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Sea Turtles of the U.S. West Coast

Life in the Higher Latitudes

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Summary

Sea turtles are typically associated with tropical sandy beaches or coral reef habitat, not with the cool and dynamic waters off the U.S. West Coast. Although some sea turtle species are indeed rare, wayward visitors during warm water events in temperate high latitudes of the eastern North Pacific, leatherbacks (*Dermochelys coriacea*) and green turtles (*Chelonia mydas*) are regularly found in this region. The California Current is known to contain some of the most productive marine habitats in the world, but little has been known about the movements and ecology of green and leatherback turtles within this ecosystem. Using a variety of research techniques, including genetic studies, satellite telemetry, aerial surveys, boat-based capture operations, and analysis of blood and tissue samples, scientists have recently uncovered some of the mysteries of these ancient mariners. Endangered leatherbacks perform trans-Pacific movements from tropical western Pacific nesting beaches to forage in offshore and neritic waters off the North American west coast during summer and fall. Drawn by dense aggregations of brown sea nettles (*Chrysaora fuscescens*) and other sea jellies, leatherbacks are rarely seen at sea, and their cryptic behavior beneath the dense fog that often blankets the west coast adds to their intrigue. In contrast with the seasonal presence of leatherbacks in the cool open sea, green turtles occur year-round in estuarine and coastal marine ecosystems within the warmer Southern California Bight. Although evidence of the occurrence of green turtles has been available since the late 1800s, scientists have only recently learned that their long-term residence in coastal embayments, most notably San Diego Bay, is a natural behavior and part of their normal life history. Aided by a warm-water effluent from a nearby power plant, the thriving

population in San Diego Bay includes the largest eastern Pacific green turtle on record and exhibits the fastest growth rates among Pacific green turtles. Large populations of whales and seabirds and important fisheries are also well-known components of the California Current ecosystem. Recent revelations about leatherback and green turtle populations in this high-latitude, temperate region have enhanced our knowledge of the diverse assemblage of marine vertebrates.

Introduction

When we think about the amazing variety of marine creatures off the U.S. West Coast, we might imagine gray whales, sea otters, or white sharks, but sea turtles usually do not come to mind. The waters of the California Current are thought to be too cold and inhospitable for these marine reptiles, which are typically associated with coral reefs, seagrass pastures, or sandy beaches in tropical climes. Until recently, occurrence of sea turtles in California was characterized as a rare, exotic event—the wayward wandering of a lost animal entrained in a warm-water pool sliding toward the coast, or perhaps in the warm-water effluent of a power plant. However, this view has changed dramatically over the last ten years as research has uncovered new information about these creatures that no doubt discovered California long before the Gold Rush. This chapter is a tale of two turtles (species) and how we now know that they are an integral part of two contrasting local marine ecosystems: leatherback turtles in the productive and dynamic upwelling regions off the central coast of California, and green turtles in the coastal lagoons in southern California (plate 1). In this chapter we describe the ecology of marine turtles at high latitudes in the eastern Pacific, providing an overview of recent discoveries as well as the stories behind the research.

Leatherbacks in the California Current Ecosystem

Habitat Overview

The California Current is among the most productive marine ecosystems in the world, supporting a diverse assemblage of marine species and large commercial and recreational fisheries. Dominated by wind-driven upwelling, these cool, nutrient-rich waters support abundant year-round resident species and attract far-ranging migratory animals that forage here seasonally, including seabirds, baleen whales, sharks, and large predatory fishes, such as swordfish and tunas. Marine turtles, a conspicuous icon of tropical latitudes, historically were considered rare visitors to these waters during warm-water periods, such as El Niño events. Recent studies, however, have brought increasing recognition of the importance of this temperate habitat as a major foraging destination for leatherback turtles, *Dermochelys coriacea*.

Leatherback turtles can tolerate extreme temperature variations and exhibit the most extensive geographic range of any reptile, including temperate waters of the northeastern Pacific. Originating from nesting beaches in the tropical western Pacific, leatherbacks perform trans-Pacific migrations to foraging grounds along the continental margin between British Columbia, Canada, and Point Conception, California, USA. They tend to arrive in coastal waters between May and August and reach peak densities during late summer and early fall, when upwelling winds begin to subside, sea surface temperatures rise, and large blooms of sea jellies (Scyphomedusae) become conspicuous. The sequence and exact timing of these events vary from year to year, influencing the development of sea jelly prey fields and the occurrence of leatherbacks.

Developing Awareness of Leatherbacks

Historically, records of leatherback occurrence in the California Current ecosystem were rare, most likely because of the cryptic nature of leatherbacks at sea. The first compilation of leatherback occurrence in the northeastern Pacific Ocean was done by a San Diego State University graduate student, based on anecdotal records, opportunistic sightings, and stranding reports going back as far as 1887 and ranging from Baja California to Alaska (Stinson 1984). Subsequent examination of stranding data and sightings made by recreational boat skippers revealed that coastal areas near Monterey Bay, California, were a common region of leatherback occurrence when sea surface temperatures reached 15–16°C during the summer months (Starbird et al. 1993). Systematic aerial surveys off the coast of Oregon and

Washington during 1989–1992 also revealed the presence of leatherback turtles there during summer months, when sea surface temperatures were warmest (Bowlby et al. 1994). Collectively, these data revealed a summer/fall occurrence pattern, but nothing was known about the significance of individual foraging areas or the population origin of leatherbacks seen off the U.S. West Coast. As recently as 1998, the Pacific Leatherback Recovery Plan (NMFS and USFWS 1998a) presumed that most of these turtles originated from eastern Pacific nesting beaches in nearby México.

The first evidence of a more complex migratory pattern came from genetic studies of leatherback turtles caught incidentally in fisheries in the central and eastern North Pacific and stranded specimens along the U.S. West Coast (Dutton et al. 2000). To the surprise of everyone, the genetic signatures (i.e., DNA sequences) of leatherbacks sampled in the central and eastern North Pacific did not match those found in nesting females in México, but rather pointed to the tropical western Pacific, thousands of miles away. The precise origin, however, was still a mystery because the western Pacific leatherback population was known to nest at multiple beaches scattered throughout Papua New Guinea, Papua Barat (Indonesia), Solomon Islands, and possibly other undocumented sites. No information on postnesting movement patterns of leatherback turtles was available for any of these beaches, but identifying links between foraging areas and nesting sites was considered critical for implementing successful multinational management and conservation actions to protect and recover this Critically Endangered species (International Union for Conservation of Nature 2010).

Planes, Boats, and Satellites

The first step in linking foraging areas and nesting sites was to locate a foraging area where leatherbacks could be studied and outfitted with satellite-linked transmitters. Although Monterey Bay, California, was known to have a seasonal occurrence of leatherbacks (Starbird et al. 1993) (plate 2), finding and capturing free-swimming turtles proved challenging. In the early 1990s Scott Eckert, a leatherback expert who had pioneered satellite tracking of sea turtles, had raised funds to charter a purse-seiner to find and catch a free-swimming leatherback in Monterey Bay. After all, how hard could it be? He set out in the dense fog that typically shrouds the central coast of California during August and September—paradoxically, also when most turtle sightings occur—crisscrossing the bay in search of leatherbacks. After several days of poor visibility, he realized this was harder than he first thought and abandoned the search.

The story picks up again in 1999, when the U.S. National Marine Fisheries Service (NMFS) was focusing resources on implementing the newly rolled-out Pacific sea turtle recovery plan, and one of the priorities at the Southwest Fisheries Science Center (SWFSC) was to address leatherback research needs. The eastern Pacific nesting populations in México and Costa Rica had collapsed in the late 1990s, underscoring the desperate need to learn more about movement and habitat requirements of these animals in the marine environment. Karin Forney, a marine mammal biologist at the SWFSC, had regularly seen leatherbacks in California while flying aerial surveys along the coast to count harbor porpoise (Forney et al. 1991). Forney had noticed, among other things, that leatherback turtles associated with dense sea jelly patches in the waters close to shore. She had the foresight to record these sightings beginning in 1990 and recorded nearly 100 observations of leatherbacks off the central California coast. Based on these sightings, the authors, together with Eckert and Forney conceived a plan to study leatherbacks using the combined efforts of an aerial spotting team to locate turtles and a boat-based team that could safely capture and bring aboard these large animals to outfit them with satellite-linked transmitters.

In September 2000, which turned out to be a particularly good year for leatherbacks in Monterey Bay, the plan went into motion. With cooperative weather, the observers in the chartered plane quickly reported several leatherbacks less than a mile off the beach. The boat-based team set off in Moss Landing Marine Laboratory's (MLML) R/V *John H. Martin* with a crew of staff and volunteers, who were astounded at their first sight of an enormous leatherback. Using a sturdy, oversized hoop net, we managed to catch the turtle and safely hauled her onto the deck of the boat despite the objections of our groaning A-frame (fig. 4.1, top). After releasing her with a satellite-linked transmitter attached, she became the first turtle to reveal the movement patterns of leatherbacks foraging in temperate waters of the northeastern Pacific.

In the following years, the capture methods were further refined, especially with the involvement of Professor Jim Harvey (MLML), who

FIGURE 4.1. (Top) First leatherback caught and sampled aboard R/V *John H. Martin* in Monterey Bay, California, September 2000 (© Scott Eckert). (Bottom) A 607-kg leatherback aboard R/V *Sheila B.*, September 2007 (© Heather Harris).

procured a custom-made boat that was better suited for leatherback in-water work. The R/V *Sheila B.* is a 35-ft Munson featuring a retractable bow that can be lowered into the water, allowing researchers to quickly slide the captured leatherback straight onto the foredeck instead of having to lift the huge creatures out of the water and onto the deck with a cargo net (fig. 4.1, bottom). During the pilot study in 2000, two free-swimming leatherbacks were safely and successfully brought aboard, which not only demonstrated that such research was possible but also provided previously unavailable access to foraging leatherbacks to study their ecology and movements.

Crossing Borders and Connecting Countries

The first four tagged leatherbacks moved southwestward from Monterey Bay, into equatorial waters and toward the western Pacific, thus confirming the original genetics results and highlighting the importance of coordinating international conservation efforts in these two regions (Dutton and Squires 2008). However, track lengths were not sufficiently long to determine nesting beach origin, reaching only as far as the Marianas Trench, north of New Guinea. Therefore, an additional tactic was adopted, and transmitters were deployed on leatherbacks at known western Pacific nesting beaches to identify postnesting movement patterns and potential links to the northeastern temperate Pacific.

The first deployments from western Pacific nesting beaches took place along the north coast of Papua New Guinea during the December–February 2001/2002 and 2002/2003 nesting seasons. All nineteen tagged leatherbacks moved southeastward toward higher latitudes of the western South Pacific near New Caledonia and Vanuatu (Benson et al. 2007c). Although these results presented important new information about the western Pacific leatherback population, they did not provide the desired link to the temperate eastern North Pacific.

The existence of a sizable leatherback nesting population on the remote northern coast of Bird's Head Peninsula (Papua Barat, Indonesia) subsequently provided a basis for additional telemetry studies in the western Pacific. Deployments conducted during the primary July nesting peak in 2003, 2005, 2006, and 2007, and during a secondary nesting peak in January–February 2005 and 2007, linked a few individuals to the U.S. West Coast (fig. 4.2), including the first recorded trans-Pacific migration of a leatherback: the turtle traveled more than 10,000 km from Papua Barat to Oregon, USA (Benson et al. 2007a). These deployments also documented additional diverse postnesting movements into tropical and temperate waters throughout the Pacific Ocean and adjacent tropical seas, including the South China Sea, pelagic waters of the central North Pacific, tropical Indonesian Seas, and the East Australia Current system (Benson et al. 2011).

Subsequent telemetry deployments on free-swimming leatherbacks captured off central California during 2002–2007 further confirmed Papua Barat beaches as nesting destinations and established an additional

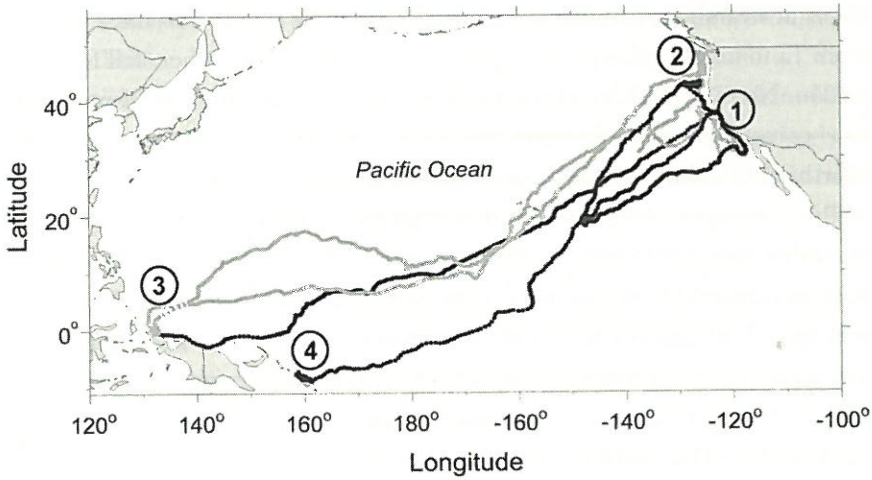

FIGURE 4.2. Western Pacific leatherback movements. Two black tracks show trans-Pacific migrations from central California foraging grounds (1) to nesting beaches in Jamursba-Medi, Papua Barat, Indonesia (3), and Santa Isabel Island, Solomon Islands (4). The third black track is a round-trip between central California and equatorial north Pacific. Gray tracks show migrations from Jamursba-Medi (3) to central California (1) and Oregon/Washington (2).

link to a previously undocumented nesting beach in the Solomon Islands (fig. 4.2). Because trans-Pacific migrations of this magnitude are energetically costly, the California Current ecosystem must be a reliable and productive foraging area for the western Pacific nesting population.

Leatherback Ecology: Foraging in the Shadows

Although there have been myriad shipboard surveys and oceanographic sampling programs in the California Current spanning many decades, the cryptic behavior and low surfacing profile of leatherback turtles make them difficult to detect and have hindered efforts to quantify their abundance and distribution. The most comprehensive information on leatherback abundance, distribution, and habitat at northeastern Pacific foraging grounds has been obtained from aerial surveys, which are the most effective method for locating and quantifying leatherbacks at sea.

Based on the sightings recorded by Forney during harbor porpoise aerial surveys, Benson et al. (2007b) estimated the abundance of leatherbacks at nearshore California foraging areas to be highly variable, ranging from 12 to nearly 400 individuals per year during the summer/fall foraging season. No multiyear trend was evident between 1990 and 2003, but a positive correlation was identified between leatherback abundance and the Northern Oscillation Index (NOI; Schwing et al. 2002), an indicator of upwelling strength. When the NOI was positive, upwelling conditions were favorable and leatherback abundance was high. Conversely, during years with negative NOI values, upwelling was poor and leatherback abundance was low. This pattern was likely linked to patterns of sea jelly abundance and distribution in nearshore waters of central California, particularly the brown sea nettle, *Chrysaora fuscescens*, a large scyphomedusa. Our observations of leatherbacks during sampling and tagging operations in 2000–2007, and deployments of a suction-cup–mounted video camera during 2008, have confirmed that leatherbacks feed almost exclusively on brown sea nettles off central California (fig. 4.3). Although sea jellies are often considered an indicator of poor ocean health (Mills 2001), brown sea nettle blooms in

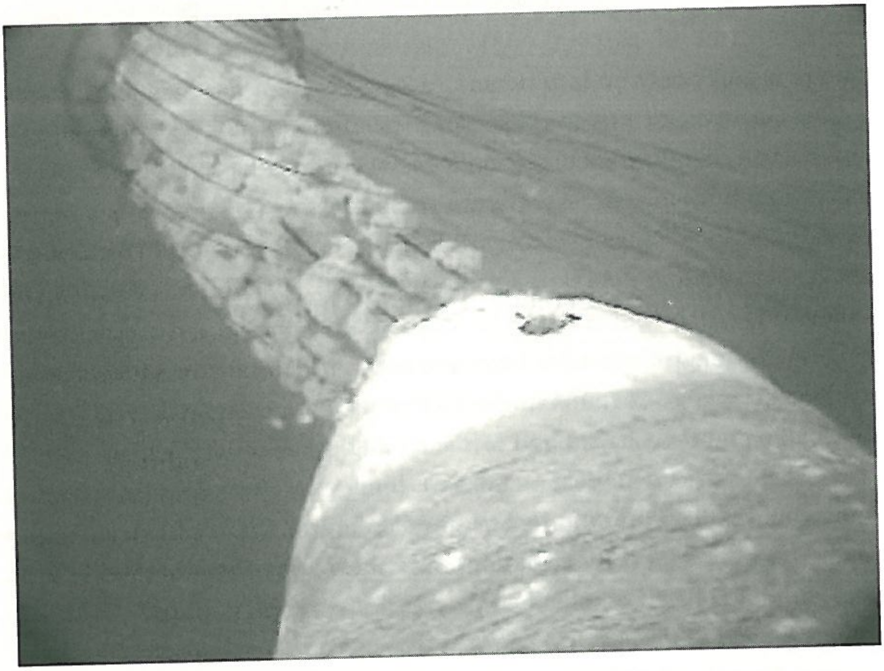

FIGURE 4.3. Leatherback with suction-cup–mounted video camera approaches a brown sea nettle off the central California coast (© Bill Watson).

coastal waters of central California have been linked to productive upwelling conditions. During years with delayed or interrupted upwelling, when productivity is reduced, brown sea nettles are rare or absent (Graham 1994; Benson et al. 2011). Sea jellies have a low nutritional value, and leatherback turtles must locate dense concentrations (about 20–30 percent of their body weigh per day) to meet their energetic needs (Davenport and Balazs 1991; Wallace et al. 2006).

The 1990–2003 aerial surveys also indicated that leatherbacks were most abundant along the central California coast between Monterey Bay (36.5° N) and Point Arena (39° N). This part of the coast is characterized by multiple headlands, bays, and submarine canyons, which interact with local hydrographic features to create localized retention areas and upwelling shadows (Graham 1994). In these regions, nutrient-rich, upwelling-modified water is entrained nearshore, particularly during wind relaxation, supporting the growth and retention of zooplankton, larval fish, crabs, and gelatinous organisms, leading to dense aggregations of the predatory brown sea nettle (Graham 1994; Wing et al. 1995; Graham and Largier 1997; Graham et al. 2001). This sea jelly has relatively high carbon content among the scyphomedusae and can sustain extraordinarily high growth rates in productive environments, making it the ideal prey for leatherbacks (Shenker 1984; Graham 2009). Not surprisingly, the greatest densities of leatherbacks were found in or near these oceanographic retention areas, where brown sea nettle abundance was greatest, including portions of the Gulf of the Farallones, northern Monterey Bay, and continental shelf habitat between Point Reyes and Bodega Bay (Benson et al. 2007b).

Similar processes have been reported off Oregon, where scyphomedusae become denser and larger in size during summer, when the movement of surface and near-surface waters concentrates plankton in nearshore retention areas (Shenker 1984; Suchman and Brodeur 2005). Telemetry data (Benson et al. 2011) and aerial surveys (Bowlby et al. 1994) show that leatherbacks also forage seasonally in such areas off Oregon and Washington, and in some years off Vancouver Island, British Columbia (Spaven et al. 2009).

The timing of arrival of leatherbacks in foraging areas throughout the California Current during May–August appears directly linked to the phenology of upwelling and sea jelly aggregation in each area. Telemetry data indicate that the earliest arrivals are turtles that foraged along the U.S. West Coast during the previous summer/fall. These individuals departed the California Current during October–December to spend the colder winter months in warmer waters of the central equatorial Pacific. Beginning in March, they approached the central California foraging areas via the Southern California Bight, where coastal water temperatures were warmest, and followed a relatively nearshore path (within about 50 nautical miles) northward toward central California. Postnesting leatherbacks that performed trans-Pacific movements from their western Pacific beaches tend to arrive later, during July–September. The approach of these individuals tends to follow a more direct, northern path toward either central California or Oregon/Washington waters. Leatherbacks appear to be mystic masters of time and space, arriving in the right place at the right time, wherever that may be.

Looking Forward

In the first decade of the twenty-first century, we have been in a period of perpetual discovery, transitioning from virtual ignorance about the origin of leatherbacks off the U.S. West Coast, to a recognition and appreciation of the complexity of the ecological seascape experienced by this population. The diversity of movements has broad implications for stock structure, foraging ecology, and conservation. As our research continues, each question answered creates two new puzzles. Why leatherbacks migrate across the Pacific to distant temperate waters of the eastern North Pacific, when other available foraging areas are closer to the nesting beaches, is a question central to leatherback ecology, evolution, and conservation. The answer may remain elusive during our lifetimes, but we hope that our research will provide some clues and tools for future inquisitive minds seeking to understand the role of leatherbacks in the California Current and other marine ecosystems of the Pacific.

Green Turtles in Southern California

In contrast to widely distributed, gigantothermic leatherbacks, green turtles (*Chelonia mydas*) spend most of their lives not in the cold waters of the California Current but instead in neritic habitats of coastal lagoons of the North American West Coast, where they feed primarily on algae and seagrasses (Dutton and Eckert 1994). Green turtles have been reported seasonally in waters along the California coast and as far north as Alaska, although in cold winter months they become moribund and strand at northern latitudes (Hodge and Wing 2000). Adult female green turtles nest on tropical beaches and then migrate, sometimes thousands of kilometers, back to their feeding grounds. The nearest nesting sites to southern California are found in the tropics along the coast of México, Central America, the Galápagos, and the Hawaiian Archipelago (plate 5). Juvenile and adult green turtles are resident year-round at feeding grounds extending along the coast of Baja California, México, and southern California, USA (plate 1).

Green turtles generally had become regarded as a rare exotic species in southern California. However, newspaper accounts indicate that sea turtles were not uncommon in the late 1800s in San Diego Bay and Mission Bay and were routinely caught by local fishermen. In addition, thousands of green turtles moved through the San Diego port, mostly brought in by whaling ships that caught them to feed their crews and then began selling them. Schooners brimming with green turtles caught on feeding grounds in lagoons at the southern end of the Baja California peninsula would come up to San Diego Bay to offload their catch (Stinson 1984). Turtle soup and meat were featured menu items at many San Diego restaurants, and in 1919 a sea turtle processing plant, Blackman Cannery, opened on the Bayfront at National City. By the 1930s, however, the sea turtles seemed to have disappeared from the public eye; the cannery had closed, and newspapers had stopped reporting sea turtles in San Diego Bay.

Turtles in the Jacuzzi

In 1984, Margie Stinson presented work for her Master's thesis about a small group of green turtles she had discovered in the south part of San Diego Bay. According to Stinson, the turtles had taken up winter residence in the effluent channel of the San Diego Gas and Electric power plant in the 1960s when it was built. The turtles had apparently been attracted to the warm water discharge from the power plant that had inadvertently cre-

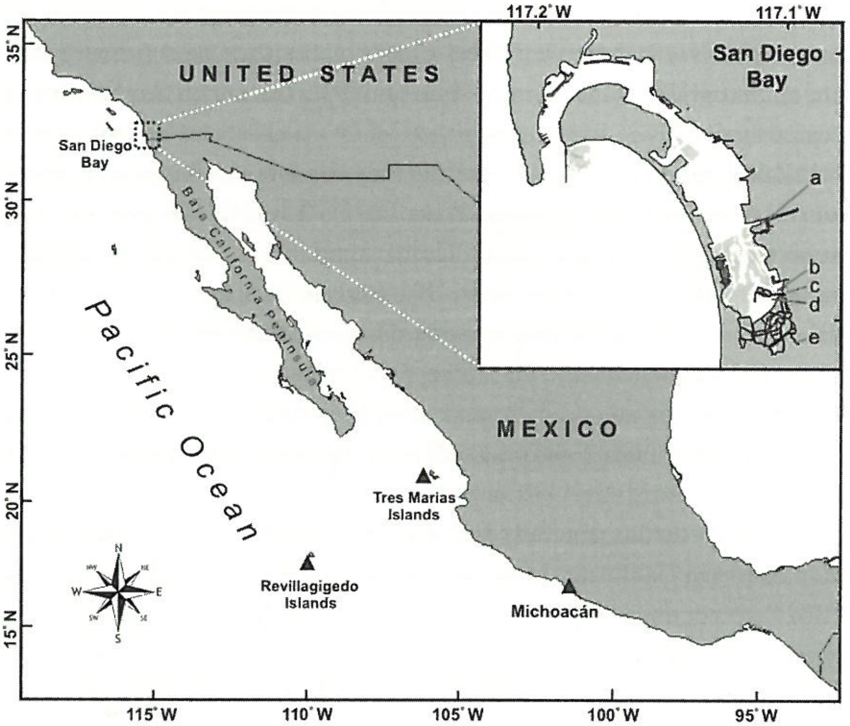

FIGURE 4.4. Map of San Diego Bay and known nesting areas for the green turtles in San Diego Bay. In the inset, gray shaded areas within San Diego Bay indicate known eelgrass habitat: (a) Sweetwater River; (b) intake channel; (c) power plant; (d) effluent channel; (e) Otay River. Known nesting areas are Tres Marías Islands, Revillagigedo Islands, and Michoacán on the mainland of México.

ated a tropical refuge in the southern part of the bay (fig. 4.4). With advice from Mexican fishermen and logistical support from U.S. Navy SEALs, Stinson captured and tagged seven green turtles, including a huge one she fondly named Wrinklebutt because of the distinctively upturned posterior end of its deformed carapace. This unmistakable turtle had been sighted by power plant workers in the 1960s, which suggested that it was a San Diego Bay regular. Wrinklebutt was recaptured in 2007 and weighed in at 241 kg (530 lbs), the largest eastern Pacific green turtle on record. Stinson used some early tracking devices to study the turtles and concluded that at least seven green turtles had moved into the "Jacuzzi"—the swirling, warm water discharged by the power plant—in November to stay warm during the cold winter months, and that they left the bay in the late spring, perhaps to breed in México (Stinson 1984).

Following Stinson's work, Donna McDonald, then at the Hubbs-Sea World Research Institute, and one of the authors (P.H.D.) conducted regular visits to the Jacuzzi, where they systematically recorded turtle sightings and water temperatures. Surprisingly, turtles were present throughout the year, even during the height of summer, when the water temperatures reached 100°F/38°C (Dutton and McDonald 1990). In 1991, McDonald and Dutton began catching and tagging the turtles, and the consistency with which turtles were captured indicated that more than just a few peculiar turtles had been lured in from the cold California Current by the warm water from the power plant. McDonald and Dutton attached ultrasonic tracking devices and confirmed that they were year-round residents, as had been observed in the lagoons in the Gulf of California, where green turtles were known to overwinter in a state of quasi hibernation when water temperatures dropped below 14.5°C (Felger et al. 1976). Perhaps green turtles, that undoubtedly had used San Diego Bay as foraging pastures long before humans arrived, were now using the warm water of the power plant to stay warm and thrive during the winter (McDonald et al. 1994).

Since then, a multitude of volunteers, researchers, and graduate students have become involved in monitoring and research of the San Diego Bay green turtles, which have now become recognized as part of the local ecosystem. The U.S. Fish and Wildlife Service, the U.S. Navy, and the Port of San Diego have partnered with NMFS to address various management mandates that concern this endangered species. A project is under way with a new generation of San Diego State University students using ultrasonic telemetry to map precise habitat use patterns within the bay.

By 2009, a total of ninety-six green turtles had been tagged, ranging in size from 44.0 to 110.4 cm straight carapace length (Eguchi et al. 2010). The smaller of these turtles would have moved recently into the bay from the oceanic waters where young juveniles live during the first years of their lives before seeking out coastal neritic feeding grounds. It is now clear that this is a viable natural population, with new turtles periodically settling into the bay and taking up long-term residence. Recaptures of some turtles first tagged in the early 1990s have revealed growth rates among the fastest reported for Pacific green turtles (Dutton and Dutton 1999); at least one ani-

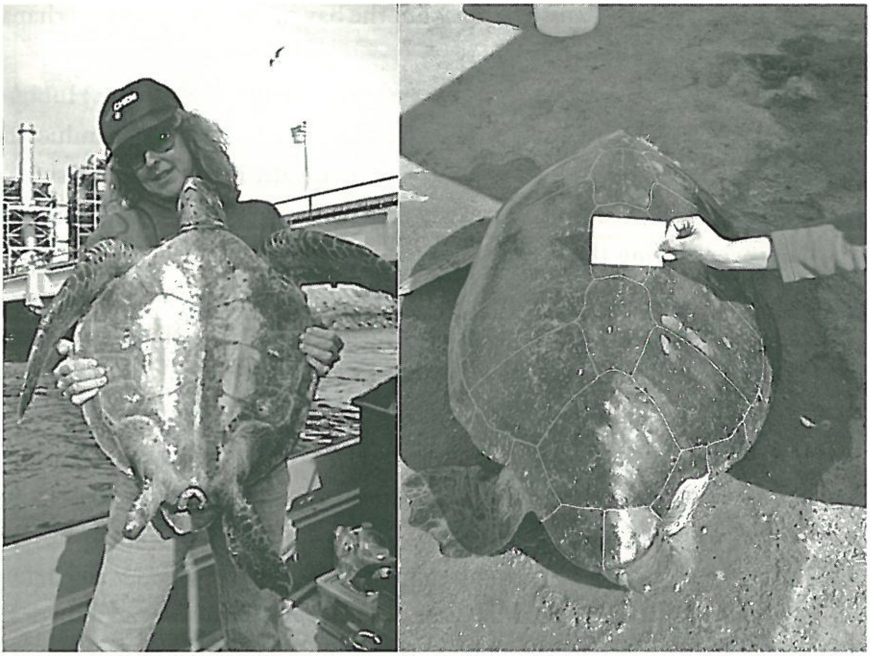

FIGURE 4.5. Donna Dutton with a small juvenile green turtle tagged in 1991 in San Diego Bay (left) and the same turtle as a mature male in 1996 (right; photos by P. Dutton). The history of multiple captures of this turtle is typical of many turtles captured in San Diego Bay: he was first captured in 1991, then again in 1996, 2004 (three times!), 2007, and 2011.

mal tagged as a small juvenile in 1991 was recaptured five years later as a large mature male; at least one animal tagged as a small juvenile in 1991 was recaptured five years later as a large mature male (fig. 4.5). Tracking revealed that the turtles were swimming over to the eelgrass pastures around the bay during the day and returning periodically to sit in the Jacuzzi and stay warm (Lyon et al. 2006). This optimal foraging strategy allows the turtles to remain active through the cold winter months and apparently reach the upper limits of their growth rate potential. New research led by Jeffrey Seminoff using stable isotope tools indicates that the San Diego Bay green turtles have a unique trophic feeding ecology compared with their conspecifics at foraging grounds farther south (J. A. Seminoff, unpublished data). This finding suggests that San Diego Bay green turtles may be growing faster and reaching maturity sooner on average than elsewhere in the Pacific, where growth rates are highly variable and generally slower (Seminoff et al. 2002; Chaloupka et al. 2004).

Origin of California Green Turtles

The green turtles in San Diego Bay and elsewhere off the coast of California were generally assumed to have originated from the nesting beaches in Michaocán, México, where thousands of eastern Pacific green turtles were known to nest (Seminoff 2004; see chapter 11). Dutton and McDonald began to discover that not all the San Diego Bay turtles had the distinct dark gray plastron and black carapace that characterized the eastern Pacific morphotype typical of the Michoacán breeding population (a.k.a. the "black" turtle). They found a variety of colors and shapes, many resembling those typical of the Hawaiian green turtles (fig. 4.6). Clearly, shape and color are not reliable diagnostics to identify the source population of green turtles found at foraging areas, so Dutton set out on a quest to solve the mystery of their stock origin using newly developed genetic tools.

Knowing which stock these turtles belong to has implications for

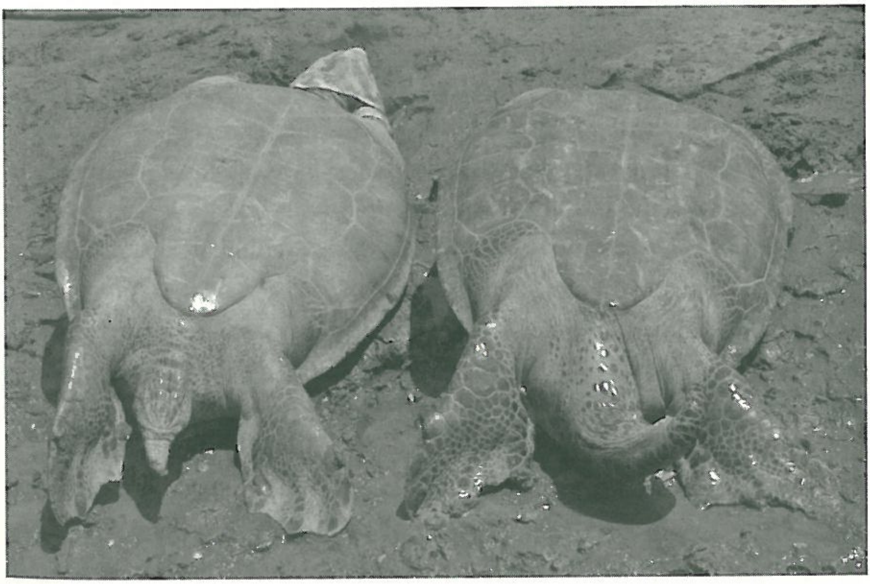

FIGURE 4.6. Color variation for green turtles in San Diego Bay (photo by J. Seminoff).

their conservation status under the U.S. Endangered Species Act, because the Mexican breeding populations are considered Endangered, whereas the Hawaiian population is listed as Threatened (NMFS and USFWS 1998b), with the main nesting population at French Frigate Shoals in the Hawaiian Islands steadily increasing over the last thirty-five years (Balazs and Chaloupka 2004). The answer was elusive for many years, because the genetic signatures of most California green turtles did not match those of the Hawaiian or the Michaocán breeding populations. Finally, Laura Sarti, with México's National Commission for Natural Protected Areas, and her team collected samples from a little-known nesting population in the Revillagigedo Islands off the coast of México that may have solved the mystery (Dutton et al. 2008). Preliminary genetic results along with satellite tracking indicate that most of the San Diego Bay green turtles are likely from Revillagigedos, although analysis is still ongoing to determine whether any are part of the Hawaiian and Michaocán breeding populations (Dutton 2003).

"Mud, Leeches, and Turtle Tumors"

Catching turtles in the shallow estuarine environment of south San Diego Bay is usually a visceral experience since it requires wallowing, sometimes chest deep, in mud to retrieve nets and observe the turtles close-up. Starting in 1991, Dutton and McDonald noticed many of the San Diego Bay green turtles had lesions and "white flecks" in the corners of their eyes. They sent photographs to George Balazs of the U.S. National Marine Fisheries Service, Pacific Islands Science Center, who had been documenting the spread of a devastating tumor disease, fibropapillomatosis (FP) among the Hawaiian green turtles, and he confirmed these eye lesions as early stages of FP (McDonald and Dutton 1990). They also noticed that these turtles were covered in small marine leeches in the axial or "armpit" areas, a condition commonly associated with FP, and genetic analysis of skin samples revealed that the herpes virus associated with FP in green turtles was present (Greenblatt et al. 2005; S. Roden and P. H. Dutton, unpublished data). However, the FP did not progress beyond these early stages in the two decades of observation, except in one case, where a turtle was found in 2001 with more than eighty small tumors. This particular turtle was captured recently and was tumor free. It is possible that the herpes virus infecting the San Diego Bay turtles is a less virulent than other strains, although the environmental cofactors associated with FP are poorly understood (Greenblatt et al. 2005). The San Diego Bay turtles appear robust and generally healthy, despite their existence in a polluted urbanized environment. A recent study detected trace metals and persistent organic pollutants in the turtles, although further work is needed to understand the long-term health consequences of accumulating these pollutants (Komoroske et al. 2011).

An Uncertain Future?

In sum, green turtles are more common than previously thought in southern California, and as research continues, we are coming to better understand that they are natural members of the estuarine and coastal marine ecosystem communities. In the summer, green turtles are increasingly sighted in the kelp beds off San Diego and in the coastal lagoons up the coast of southern California. A resident green turtle population has been discovered in the San Gabriel River in Los Angeles, associated with the warm-water discharge of another power plant. Although green turtles are associated with the warm-water effluent from power plants along the coast, their long-term residence in coastal embayments, most notably San Diego Bay, is a natural behavior that is part of their normal life history. The San Diego Bay turtles face continued challenges as they try to share the bay with a growing human population and burgeoning coastal development. Ironically, their most immediate environmental challenge will come from the removal of the power plant that has kept the southern portion of the bay comfortably warm for them. After several years of decreasing power generation, the aging power plant was finally decommissioned in late 2010 and is scheduled to be completely dismantled by 2014. What will the turtles do without the plume of warm water? We are fortunate to have two decades of data on the biology, habitat use, and behavior of this population that will serve as a baseline to monitor changes resulting from the shutdown.

Currently, the greatest threat to the San Diego Bay green turtles has been from boat strikes, which have been associated with most of the dead turtles that have been found. The relative seclusion of the high-use area within a southern portion of the bay, which was established as a wildlife refuge, has provided a haven away from the heavy boat traffic throughout the central and northern part of the bay, but if the turtles disperse to other areas, they will have to increasingly dodge this boat traffic to avoid injury. Perhaps they will remain mostly in the southern portion and dig into the mud to sleep during the winter if the water cools enough, just like their ancestors did before humans built the city and changed their environment. Whatever the turtles do, local, regional, and federal agencies now recognize that the southern California green turtle residents need to be accounted for in management and development decisions that affect the coastal ecosystems they depend on for their survival and species recovery.

ACKNOWLEDGMENTS

Investigations of leatherback turtles in the challenging coastal environment of central California would not be possible without the support of many colleagues and volunteers. We thank the staff of the Marine Operations Department at Moss Landing Marine Laboratory, particularly J. Douglas, L. Bradford, and S. Hansen, for their efforts to keep us safe and close to the turtles. Finding leatherbacks would have been impossible without the support of the pilots and crew of Aspen Helicopters, Inc., and the many aerial observers that have participated in the surveys, especially K. Forney, E. LaCasella, and K. Whitaker. We thank J. Harvey, B. Watson, and multiple cohorts of MLML graduate students for their enthusiasm, input, and participation in the foraging ecology studies. S. Eckert originally noted the significance of leatherback turtle sighting data collected during the aerial surveys and provided the initial inspiration and expertise for in-water sampling and tagging studies. Financial support and personnel were provided by the U.S. National Marine Fisheries Service (Southwest Fisheries Science Center, Southwest Region, and Office of Protected Resources). Leatherback research was conducted under NMFS scientific research permits 1227 and 1596. Aerial surveys were conducted under NMFS permits 748 and 773-1437, and National Marine Sanctuary permits GFNMS/MBNMS-03-93, MBNMS-11-93, GFNMS/MBNMS/CINMS-09-94, GFNMS/MBNMS/CINMS-04-98-A1, MULTI-2002-003, and MULTI-2008-003. Green turtle field studies in San Diego Bay were inspired by Margie Stinson, encouraged by George Balazs, and initially led by Donna McDonald-Dutton with help from numerous volunteers over the years, notably Stephen Johnson, Marilyn Dudley, Elyse Bixby, Amy Frey, Luana Galver, Lauren Hansen, Lauren Hess, Amy Jue, Erin LaCasella, Vicki Pease, Dan Prosperi, Suzanne Roden, Manjula Tiwari, Boyd Lyon, and Lisa Komoroske. Tomo Eguchi, Robin LeRoux, and Jeff Seminoff were co-principal investigators with Peter Dutton in recent years. Don Waller, Kent Miles, and Chris Hawkins of San Diego Gas and Electric Co., Tom Liebst of Dynergy, and Eileen Mahler of the Unified Port of San Diego shared information and helped with logistics. Funding and other resources were provided by the San Diego Fish and Wildlife Commission, the U.S. Fish and Wildlife Service, Hubbs-Sea World Research Institute, San Diego State University, and NOAA—U.S. National Marine Fisheries Service. Research in San Diego Bay was conducted under NMFS scientific research permits 697, 988, 1297, and 1591 and California Department of Fish and Game permit 0411.

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Sea Turtles of the Eastern Pacific
Advances in Research and Conservation

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Foreword by Peter C. H. Pritchard

THE UNIVERSITY OF
ARIZONA PRESS

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www.uapress.arizona.edu

Library of Congress Cataloging-in-Publication Data
Sea turtles of the eastern Pacific : advances in research and conservation / edited by Jeffrey A. Seminoff and Bryan P. Wallace ; foreword by Peter C. H. Pritchard.
p. cm. — (Arizona-sonora desert museum studies in natural history)
Includes bibliographical references and index.
ISBN 978-0-8165-1158-7 (cloth :alk. paper) 1. Sea turtles—Pacific Ocean. 2. Sea turtles—Conservation—Pacific Ocean.3. Sea turtles—Research—Pacific Ocean. I. Seminoff, Jeffrey A. (Jeffrey Aleksandr) II. Wallace, Bryan P.
QL666.C536S44 2012
597.92'809164—dc23

2011051602

Publication of this book is made possible in part by a grant from NOAA—National Marine Fisheries Service.

Manufactured in the United States of America on acid-free, archival-quality paper containing a minimum of 30 percent post-consumer waste and processed chlorine free.

17 16 15 14 13 12 6 5 4 3 2 1